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Mechanical and chemical processes affecting the chalk during burial, insights from combined reflection seismics, well data and field work

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The chalk must undergo several phases of grain reorganisation and chemical reactions during its diagenetic evolution from a carbonaceous ooze to a sedimentary rock. Some of these transformations could be observed on structures from the kilometre- to the micrometre-scale with seismic reflection and cores analyses, respectively. However, few sites allow to combine all the different scale of observation for chalk diagenesis. Onshore and offshore high resolution seismics, two fully cored >350 m wells with wireline logging tools and very high quality exposures from a coastal cliff and a quarry form such an exceptional dataset in the Stevns peninsula area, eastern Danish Basin (Denmark). The studied chalk interval in the area is of Maastrichtian to Danian age. The chalk has been divided in 4 lithofacies, chalk-marl alternations, white chalk, white chalk with flint layers and bryozoan chalk. Advanced stratigraphic works have been performed with astronomical calibration based on stable isotope stratigraphy, wireline logs as well as several palaeontological proxies and detailed sedimentological analysis.

Since a couple of decades, a specific kind of fractures has been described in the Chalk of Denmark, the so-called hairline fractures. They have recently been interpreted as compaction bands associated with the pore collapse of the chalk. We have observed these fractures on the field and on the cores in specific intervals. At depth, these fractures are in genetic relation with the formation of some stylolithes. The pressure-solution allows the formation of carbonate seams in the hairline fractures. At larger scale, on the field are observed faults which are sealed with flint precipitations. They slightly offset (<1 m) strata underlined by flint bands. On the onshore and offshore seismic reflection profiles, numerous strata-bound faults form noisy intervals as well as amplitude anomalies. Their normal offsets are less than 25 m. Their branching patterns, and their restriction to certain stratigraphic intervals (mainly white chalk) is comparable to the observations made on the cores and on the field.

We consider that all these features observed at different scales record different diagenetic phases responsible of the transformation of a soft ooze into a rock. It is suggested that after deposition of nanofossil ooze, the water starts to escapes and the ooze compacts into a granular sediment. This phenomenon is associated with the strata bound faults. Later on, the flint starts to precipitate along the strata but also the faults. The pore space continuously reduces with burial and the compaction bands form. Ultimately, stylolithes appear and the remobilised carbonates seal the remaining pore space preferentially along the fractures (the compaction bands). The link between these different features has been realised thanks to the simultaneous analyses of large-scale geophysical data and small-scale core and field geological observations, providing a better understanding of the complex processes of lithification of carbonates.